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COMPILATION OF UNPUBLISHED MATERIALS INFORMATION

REPUBLIC AVIATION CORPORATION

Farmingdale, L.I., N.Y.

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REPUBLIC AVIATION CORPORATION

Farmingdale, L.I., N.Y.

NOTICE

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FOREWORD

This progress report was prepared by the Republic Aviation Corporation, Farmingdale, New York, under USAF Contract AF33(616)-8084. The contract was initiated under Project No. 1(8-7381), Task No. 73812 "Compilation of Unpublished Materials Information on Company Sponsored Programs". This work was administrated under the direction of the Applications Laboratory, Materials Central, Directorate of Advanced Systems Technology, Aeronautical Systems Division, with Mr. F. Giese acting as project engineer.

This second semi-annual progress report (final report of the contract) summarizes Republic's activities on current materials programs.

The materials programs reported in this compilation are the results of the efforts of many Republic personnel. Since a list of contributing personnel would be too cumbersome, only the departments responsible for the compilation and editing of the programs presented herein are noted. These were as follows: Manufacturing Research and Processes Department (Metallic, Nonmetallic, and Welding), Production Engineering Structures and Materials Test Section, Production Engineering Electronic Systems Analyses Section, Applied Research and Development Laboratories (Materials, Fluids, Guidance, and Electronics), and Technical Publications.

This program was coordinated at Republic Aviation by Ronald W. McCaffrey of the Applied Research and Development Materials Laboratory (Applications Group).

ABSTRACT

Summaries are presented covering some of the many materials programs being conducted at the Republic Aviation Corporation. These programs are conducted under company sponsorship and in support of contractual commitments. The summaries reflect the scope of Republic's non-proprietary materials research on metallics and special purpose materials in the areas of fundamental research, applied research and development, engineering evaluation, processing development, and testing techniques. The programs described herein vary in complexity from a sophisticated study of fracture phenomena to a routine evaluation of crazing in acrylics. Each summary describes the objective and current progress of the materials programs reported.

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INTRODUCTION

The environmental and design requirements necessitated by current and advanced aerospace vehicles have created a myriad of divergent material requirements. In order to cope with the critical dependence of new vehicles on materials and to form a foundation for future materials programs, Materials Central has initiated a program to assemble timely resumés of current materials programs being conducted within the aerospace industry.

The materials programs included in this report have been selected from Republic's current non-proprietary laboratory programs. These programs are being conducted under company sponsorship or in support of contractual commitments.

To assist the user of this report each resumé has been classified as to the type of materials program (i.e. either fundamental research, applied research and development, engineering evaluation, processing development, or testing techniques) and material classification.

Type of Program: Fundamental Research

Material Classification: General Metallics

Descriptive Title: A Study of Fracture Phenomena

Objective: The program is a theoretical solid state investigation whose objective is to determine the interaction of dislocations resulting in microcrack formation when a crystalline solid is subjected to rapidly applied, high intensity stresses. (Contract AF29(601)-2869).

Abstract of Results and Conclusions: A theoretical investigation has been made of the dynamic behavior of dislocations in anisotropic media. It is found that edge dislocations display an anomalous behavior; viz., there is a range of velocities for which edge dislocations of like sign attract rather than repel one another. The behavior of a screw dislocation depends on whether it involves one or three components of elastic displacement. For those orientations for which only one component is required, the screw behaves normally at all velocities up to its limiting velocity, i.e., the force between two like screws is always positive and goes to zero at the limiting velocity. For arbitrary orientations for which three components of displacement are required, a screw dislocation may also display an anomalous dynamical behavior, i.e., for certain velocities like screws may attract. This reversal in sign of the force between like dislocations is relevant to fracture phenomena since a coalescence of dislocations can lead to microcrack formation.

Application of the theory has been made to various materials; different crystal types and slip systems have been considered.

Results to date appear in the following papers by L. J. Teutonico.

1). "Dynamical Behavior of Dislocations in Anisotropic Media," The Physical Review, November 15, 1961.

2). "Moving Edge Dislocations in Cubic and Hexagonal Materials," The Physical Review, March 1, 1962.

3). "Uniformly Moving Dislocations of Arbitrary Orientation in Anisotropic Media," submitted for publication in The Physical Review.

Type of Program: Fundamental Research

Material Classification: General Metallics

Descriptive Title: Effect of Thermal Fluctuations on Strain Amplitude Dependent Damping

Objective: To develop the quantitative dislocation damping theories necessary to correlate damping measurement test data.

Abstract of Results and Conclusions: The mechanical theory of Granato and Lucke (Journal of Applied Physics, June 1956) for the strain amplitude dependent internal friction of solids containing dislocations applies only at absolute zero. Simple theoretical calculations show that the effect of thermal fluctuations should be very important. To extend the theory to finite temperatures, a detailed study of the possible static equilibrium configurations of a pinned dislocation is required. Two specific cases have been treated: that of a dislocation with a single pinning point, and that of a continuously pinned dislocation. By considering the kinetics of breakaway, a temperature dependent theory of the decrement and modulus change due to dislocations is being developed.

Two joint papers on this subject, prepared by Dr. Teutonico of Republic Aviation in collaboration with Dr. Granato of University of Illinois and Dr. Lucke of Technische Hochschule, Aachen, West Germany, will be presented at the March 1962 meeting of the American Physical Society in Baltimore, Md.

Type of Program: Fundamental Research

Material Classification: Chemical Kinetics

Descriptive Title: Chemical Kinetics of Combustion

Objective: To establish a simplified computer procedure for calculating the combustion rate of hydrogen in air at elevated temperatures.

Abstract of Results and Conclusions: A theoretical study of the chemical kinetics of supersonic combustion is being conducted. The kinetic equations for the hydrogen-air system, at high temperature and low density, can be simplified by considering the mixture to be in partial equilibrium so that the molecular weight is a key variable. This approach has simplified the previous requirements of solving a set of simultaneous nonlinear differential equations to one of solving ordinary simultaneous equations and performing a single integration. The final equation is written for the rate of change of the reciprocal of molecular weight in terms of the recombination rate constants. The chemical composition is uniquely determined by the molecular weight, static temperature, and static pressure at a given point.

Considering the molecular weight as a key variable has also permitted Bray's criterion to be extended to a multicomponent system. The rate of change of the reciprocal of the molecular weight, in a multicomponent system, was found to play the same role that the change in mole fraction of one component plays in a two-component system. This program is being extended so that Bray's criterion can be tested by more rigorous methods.

A paper entitled "A Simplified Kinetic Model for Multicomponent Mixtures" will be presented at the April meeting of the Combustion Institute in Los Angeles.

Type of Program: Applied Research and Development

Material Classification: Steel

Descriptive Title: Structures of Deformed Steel

Objective: 1. To determine the fundamental substructural characteristics of ausformed steel. 2. To apply the knowledge gained from the above to improve the mechanical properties of heat treatable steels.

Abstract of Results and Conclusions: The present study is focused on an attempt to interpret microstructural changes occurring in the various stages of ausforming or martensitic transformation. The study of substructural elements in steel has been continued. Insight into the fundamental phenomenological structure of the materials studied has been considerably extended. Electron microscopic thin film transmission studies and electron diffraction techniques had to be further refined to meet the specific requirements of this type of study.

The role of prior thermal history on the substructure is being investigated. Preliminary experimental data indicate that the morphology of the substructure can be greatly modified by variation of heat treatments prior to transformation.

Results obtained so far encourage extension of this investigation to a greater variety of steel compositions in order to study the influence of alloying elements on the substructure.

Type of Program: Applied Research and Development

Material Classification: Refractory Alloys

Descriptive Title: Joining of Refractory Metals

Objective: Study of parameters for optimizing the ultrasonic welding of thin gauge Refractory Metals.

Abstract of Results and Conclusions: A 4 KW ultrasonic welding unit (Aeroproject) was used for studying the ultrasonic joining of thin gauged refractory metal alloys (0.005 to 0.010). Materials studied to date have included Moly-1/2 Ti, Tantalum-10W% Tungsten, and pure tungsten. Full machine power is required for welding of the 0.010" materials by present techniques. Short weld cycles tend to minimize notch sensitivity of the joints. The shear strength of properly made ultrasonic welds is equivalent or superior to the strength of resistance welds. Ultrasonic welding is superior to resistance welding for those metals that tend toward recrystallization embrittlement, such as tungsten. Excessive wear of the weld tip and anvil requires frequent dressing to obtain reproducible weld performance. Improved tip materials and work preheating techniques are under investigation.

Type of Program: Applied Research and Development

Material Classification: Refractory Metals

Descriptive Title: High Temperature Fastener Development Program

Objective: To design, fabricate, and test structural mechanical fasteners having an efficient utilization capability in the temperature range 200 - 4500°F. (Contract AF33(616)-8104).

Abstract of Results and Conclusions: Four refractory materials have been ordered for initial fastener manufacture. These materials include molybdenum alloys (TZM and TZC) and columbium alloys (D-35 and D-36). Fastener manufacture has been subcontracted to Standard Pressed Steel, Huck, and Voishan. Eight fastener configurations, including rivets, bolts, nuts, and blind fasteners of various sizes, have been selected for initial fabrication. Other configurations are still under consideration.

Type of Program: Applied Research and Development

Material Classification: Refractory Alloys

Descriptive Title: Evaluation of Electron Beam Melted Refractory Alloys

Objective: To evaluate the mechanical properties and metallurgical characteristics of electron beam melted refractory alloys.

Abstract of Results and Conclusions: Sheath rolling studies are currently under way with a binary tungsten-molybdenum alloy. Compaative studies are being made on the workability of as received centrifugally cast material and as received material that has been subsequently electron beam melted. Micro structure and mechanical properties are also being evaluated.

Tantalum based ternary alloys are also being studied. These alloys are being prepared by electron beam melting techniques and a combination of electron beam melting and arc melting techniques. Difficulty has been observed in containing volatile additions during electron beam melting. By using the combination melting technique together with partial pressures of inert gases, definite interstitial impurities can be introduced. Evaluation of micro structure and mechanical properties will be made on these materials after they are rolled into sheet.

Type of Program: Applied Research and Development

Material Classification: Non Metallics - General

Descriptive Title: Effect of Vacuum - UV Exposure On Materials

Objective: To determine changes in solar absorptance and weight loss associated with exposure of materials to high vacuum and ultraviolet irradation.

Abstract of Results and Conclusions: Both organic and inorganic materials are being evaluated. Typical materials being investigated are ZYTEL 101, NRC Mylar base Super insulation, Sicon A (white paint), Carroll #1019 Epoxy base paint and Lockheed Paints 1747 and 10619.

The test equipment consists of an ultra high vacuum system which pumps out a chamber containing the ultraviolet source and samples. Vacuum attainable in the chamber is 10^{-9} TORR. The ultraviolet intensity is equivalent to 6 suns. Means for controlling sample temperature are included.

Type of Program: Applied Research and Development

Material Classification: Seals and Fluids

Descriptive Title: Design and Development of a 1000°F Hydraulic System

Objective: To develop a 1000°F, 4000 psi hydraulic system. (Contract AF33(616)-7454).

Abstract of Results and Conclusions: A fluid selected in an earlier phase of this program was further tested and analyzed to determine the effects of temperature, operation, and nuclear radiation. State-of-the-art surveillance of fluids has been maintained. Fluid properties required for system design and evaluation have been determined.

Seals for dynamic application were also tested. These included the Bar X rod seal and the Precision piston rings. These rings were used for both rod and Graphitar piston rings. Two Republic Aviation proprietary seal designs using Armour Research Foundation metal fiber composites and other promising alloys were tested in both primary and secondary rod seal applications with excellent results. One set of metallic seals operated for 86 hours in a primary seal application for a total of 535,000 cycles with no measurable leakage. The temperature range was -65°F to 650°F and the pressure was 80 to 4,000 psi. Another set operated for 33 hours in a secondary seal application between room temperature and 1000°F and between 80 to 100 psi without leakage. Twelve of the 33 hours were between 900°F and 1000°F, including 5 hours which were at 1000°F.

The same fiber metal composites were used with success as crush gaskets in static seal applications. Also tested for this same application were the following: - Instra-Tech seals, silver plated metallic O-rings, Skinner Spring seals and Harrison K seals.

Results of these tests are being evaluated for design application.

Type of Program: Applied Research and Development

Material Classification: Seals and Fluids

Descriptive Title: Gas Chromatographic Analysis of High Temperature Hydraulic Fluid

Objective: To identify, by gas chromatographic analysis, the products of degradation limiting the performance of high temperature fluids. (Contract AF33(616)-7454).

Abstract of Results and Conclusions: Used and unused bis (phenoxyphenyl) ether hydraulic fluids have been analyzed for the major components of the fluid and trace impurities. The degradation of the fluid has been studied to determine the effect of temperature (700° - 1000°F), pressure (300 - 500 psi), and metallic surfaces.

Work has continued on the gas chromatographic analysis of used and unused bis (phenoxyphenyl) ether hydraulic fluids. The fluid as received is a mixture of five isomers, ortho-ortho, ortho-meta, ortho-para, meta-para and para-para. At elevated temperatures there is an increase in the meta and para diphenoxybenzene in addition to the formation of m-phenoxyphenol, phenyl ether, phenol and benzene and such volatile pyrolysis products that are not separated on the chromatographic column.

Type of Program: Applied Research and Development

Material Classification: Coatings

Descriptive Title: Oxidation Characteristics of Chrome Plated Columbium

Objective: To evaluate the oxidation characteristics of chrome plated columbium under brief exposure to elevated temperature.

Abstract of Results and Conclusions: A series of preliminary static oxidation tests were performed on several chrome plates and several uncoated columbium alloy specimens. The exposure times investigated varied between 1 and 20 minutes over the temperature range of 1600° to 2300°F. The test data indicated that the alloy must be protected from oxidation for exposure times of approximately 1 minute at temperatures of 1600°F and above. The chrome plated specimens stood up rather well, exhibiting less than 1/2% weight change, little change in hardness, and less than 10% reduction in thickness after 5 minutes at 2000°F. On the other hand, the uncoated specimens exhibited a 5% weight change, 150% increase in hardness, and a thickness reduction greater than 10%.

Type of Program: Applied Research and Development

Material Classification: Coatings

Descriptive Title: Refractory Coatings Program

Objective: To evaluate oxidation resistance coatings for refractory alloys.

Abstract of Results and Conclusions: Comparative oxidation tests were performed on coated Mo-1/2 Ti sheet specimens that had been given various pre-coating edge treatments. These tests confirmed that tumbling is the superior method of preparing edges for oxidation coating. Testing has been conducted in a mildly dynamic oxidizing environment between 2000 and 3000°F.

Several Mo-1/2 Ti corrugated sheet assemblies, possessing various commercial coatings, were tested. The commercial coatings included Chromalloy's W-2, Pfaudler's PFR-6 and Chance Vought's Pack Cementation Coating. The testing included initial exposure to 2500°F for 1 to 3 hours and then random motion vibration at room temperature. All of the assemblies failed in less than 8 minutes during the vibration tests.

Preliminary oxidation tests have also been conducted on proprietary coatings developed for tungsten and tantalum alloys. Initial test results of 2-1/2 hours at 3300°F have encouraged further development of these coatings.

Type of Program: Applied Research and Development

Material Classification: Miscellaneous Special Purpose Materials

Descriptive Title: Coherent Light Generation

Objective: To develop a high power, continuously operating optical maser (laser).

Abstract of Results and Conclusions: The scope of the program includes the following:

1). The study and construction of a liquid laser test setup.

2). Experimental and theoretical materials research.

3). The study of novel pumping schemes.

4). Theoretical studies concerned with the modulation and demodulation of laser signals.

Progress to date includes construction and operation of a ruby laser as well as construction of apparatus for a liquid laser. Work is continuing on materials study for suitable liquid solutions of rare earth salts such as europium chloride in water. Organic solutions such as naphthalene and benzophenone in alcohol are also being examined.

Type of Program: Applied Research and Development

Material Classification: Miscellaneous Special Purpose Materials

Descriptive Title: Fabrication of Mylar Inflatable Structures

Objective: To evaluate techniques and procedures for constructing Inflatable Antennas utilizing mylar-aluminum-mylar laminates.

Abstract of Results and Conclusions: Leakproof sealing methods, compatible with mylar-aluminum-mylar laminates, are currently under investigation. Various heat sealing techniques are being evaluated with specific emphasis on rate of heating, sealing temperature, and bonding pressure. Representative bonds of several sealing methods have been evaluated in simple tensile tests. These tests have shown that it is possible to seal mylar to itself and to achieve a bond strength essentially as strong as the parent material. Construction of various configurations useful for inflatable antennas leads to problems of sealing along curves where wrinkling of the material is a problem. Special shaping and sealing to avoid such difficulties is also being examined.

Type of Program: Applied Research and Development

Material Classification: Miscellaneous Special Purpose Materials

Descriptive Title: Ablation Model Testing

Objective: To evaluate the ablation characteristics of various materials under various thermal loadings.

Abstract of Results and Conclusions: Preliminary ablation testing has been performed on various materials and model configurations. Materials evaluated included graphite, copper-phenolic-asbestos composites, teflon, and various reinforced resins. The tests, simulating specific thermal flight profiles, were run in a megawatt arc jet. Enthalpy levels of 4340 to 8550 BTU/lb have been studied in the presence of nitrogen, flowing at 2000 standard cubic feet per hour. Model test temperatures have exceeded 3200°F. Duration of testing has varied from 30 seconds to 2 minutes.

Type of Program: Engineering Evaluation

Material Classification: Aluminum

Descriptive Title: Cracked Rivet Investigation

Objective: To determine the critical use time for AN470DD6 (ice box) rivets to avoid cracking during installation. To evaluate the effect of cracked rivets on joint strength.

Abstract of Results and Conclusions: The initial phase of this program entailed the installation of AN470DD6 rivets in aluminum sheet after various ice box removal times. The removed times investigated varied in 10-minute intervals from 10 minutes to 120 minutes. A group of ten rivets was evaluated for each removal time. Riveting was accomplished with automatic equipment. The rivets were inspected both visually and at 10X magnification after installation. Initial cracking, in the rivet tails, was detected after a 30-minute removal time. At 70 minutes, 100% of the rivets cracked.

The second phase of the program entailed the evaluation of riveted lap shear joints using cracked rivets. Static tension tests were conducted at room temperature. The test data indicated that the presence of cracked rivet tails did not affect the strength of the joint.

Type of Program: Engineering Evaluation

Material Classification: Aluminum

Descriptive Title: Triple Action vs. Coin Dimpling of 2024-T81 and -T86 Aluminum Alloy Sheet

Objective: To evaluate triple action dimpling as a potential production method.

Abstract of Results and Conclusions: A series of room temperature tests have been conducted on triple action dimpled and coin dimpled joints in 2024-T81 and 2024-T86 sheet. The program included tension-tension fatigue and static tension tests on two gage combinations (.040/.040 and .060/.060). The fatigue tests were run at 40% and 67% of the static ultimate at a stress ratio of R = 0.1. The test data are currently being analyzed. The report will be completed within the next month.

Type of Program: Engineering Evaluation

Material Classification: Aluminum

Descriptive Title: Chemical Milling of 2024-T81 and -T86 Aluminum Alloy Sheet

Objective: 1. To evaluate the effects of chem milling on mechanical properties.

2. To evaluate the effects of chem milling, one vs. both sides of the sheet, on fatigue strength.

Abstract of Results and Conclusions: Test specimens were prepared from .102 gauge sheet chem-milled, on one or both sides, to various thicknesses. The final nominal thicknesses of one side chem-milled sheet included .045, .055, and .085 for the -T81 material and .045, .065 and .085 for the -T86 material. Additional -T86 material was chem-milled on both sides to .063.

Flexural fatigue tests were performed by constant cycling at 1000 c.p.m. at maximum stresses of 20, 30 and 40 KSI respectively. All testing, both static tension and flexural fatigue, was conducted at room temperature. Surface roughness was recorded.

The results of this test program indicated that

1). Increased amounts of chemical milling have little or no effect on the static tensile properties of both materials.

2). Increased amounts of chem milling result in serious decreases in mean flexural fatigue life (at constant stress).

3). For -T86 material, chem-milling both sides of the sheet results in a greater loss in mean fatigue life (at constant stress) than chem milling one side of the sheet.

Type of Program: Engineering Evaluation

Material Classification: Aluminum

Descriptive Title: Evaluation of X2020-T6 Aluminum Alloy Extrusions and Forgings

Objective: To evaluate the mechanical properties of extruded and forged products.

Abstract of Results and Conclusions: A series of room temperature tensile, compressive and axial fatigue (R = .10) tests were conducted on .094 thick extruded tee and angle sections. Tensile tests were also conducted on 13 x 4-1/2 x 4-1/2 closed die forgings. The test results have verified the brittle characteristics inherent in other products of X2020. Test specimens were removed from the forging in the three primary directions, longitudinal, long transverse and short transverse. The forging test data, in the three primary directions, indicated ultimates ranging from 71 to 85 KSI, yields ranging from 69 to 83 KSI, and elongations ranging from 1.0 to 5.0%. It should be noted that 0.2% yield strengths could not be determined in either the long transverse or short transverse directions because of brittle failure. The extruded material was only tested in the longitudinal direction. This product exhibited laminated fractures and general notch sensitivity.

The extrusion test data were typified with tensile ultimates ranging from 82 to 94 KSI, tensile yields ranging from 78 to 88 KSI, elongations of 5.0% to 7.0%, and compression yields of 81 to 88 KSI.

Type of Program: Engineering Evaluation

Material Classification: Titanium

Descriptive Title: Evaluation of Ti-8Al-10V Alloy Sheet

Objective: Preliminary evaluation of mechanical properties of Titanium alloy Ti-8Al-10V using .053 gage sheet material at room and elevated temperatures.

Abstract of Results and Conclusions: Room temperature tension tests are in progress in order to select the better of two aging treatments: (a) hold at 1000°F for 4 hours, air cool or (b) hold at 1050°F for 1-1/2 hours, air cool. It is then planned to conduct room temperature tension tests using the selected treatment on smooth (long and transverse) and notched specimens (transverse) with K_T = 3.0, 6.3 and 20.0 respectively. Short time, elevated temperature tension tests will be conducted in the 400°F to 1000°F temperature range. This program also includes room temperature longitudinal and transverse bend tests as well as thermal stability tension tests at room temperature after prior exposure to 800°F for 10 hours and 100 hours respectively.

Type of Program: Engineering Evaluation

Material Classification: Beryllium

Descriptive Title: Evaluation of Hot-Pressed Beryllium Sheet - Nuclear Metals

Objective: To determine mechanical properties of hot pressed Beryllium disks.

Abstract of Results and Conclusions: Room temperature tensile tests have been conducted on beryllium specimens prepared from a 7-inch diameter and a 20-inch diameter (.040 thick chem milled from .050 as received thickness) hot pressed disks. The 7-inch disk was found to possess good ductility (8.0-9.0%) with an excessive spread between tensile ultimate and tensile yield, i.e., 65-69 KSI compared to 35-39 KSI. Similar tests on the 20-inch disk showed a desirable spread between tensile ultimate and tensile yield (i.e., 61-68 KSI compared to 58-60 KSI) but very poor ductility (0.75 to 2.0%). Extensive laminations were visible in the latter test specimens. Failure was probably initiated in these areas at a premature level.

Type of Program: Engineering Evaluation

Material Classification: Iron and Steel

Descriptive Title: Elevated Temperature Compression Testing of Meehanite

Objective: To determine the effect of various compression strengths of Meehanite (HS) castings at elevated temperatures.

Abstract of Results and Conclusions: Compression tests are currently being run on a series of 1-inch diameter by 3-inch long cast specimens. The tests are being conducted at room temperature, 1000°, 1400°, 1600° and 1800°F in conformance with the recommendations of ARTC-13-C. Elevated temperature specimens are tested after various times of exposure, ranging from 1/2 to 4 hours. The test program will be completed within the next few months.

Type of Program: Engineering Evaluation

Material Classification: Iron and Steel

Descriptive Title: Dimpling of Heat Treated 17-7PH Stainless Steel

Objective: To determine if heat treated 17-7PH (TH-1050) can be satisfactorily dimpled to produce acceptable joints.

Abstract of Results and Conclusions: Dimpling of heat treated material will avoid problems of dimensional growth inherent with predrilling and dimpling PH stainless steels prior to heat treat. In order to verify the feasibility of post-heat-treat dimpling, a series of lap shear joint specimens is being evaluated at room temperature in static tension and in axial fatigue (R = .1). The specimens have been designed with four different gage combinations, ranging from .020 to .072, and three types of flush fasteners (AN427M rivets, HS-67 rivets and AN509 screws). The fastener diameters range from 1/8 to 1/4 inches. Both pre-heat-treat and post-heat-treat dimpling procedures are being evaluated.

Type of Program: Engineering Evaluation

Material Classification: Plastics

Descriptive Title: Dielectric Constant Measurements at Ka-Band Frequencies

Objective: To evaluate the dielectric characteristics of several plastic materials, with controlled resin content, as a function of Ka-band frequencies.

Abstract of Results and Conclusions: Dielectric measurements are being made with a Ka-band microwave bridge circuit (interferometer), assembled in accordance with the methods described in ARTC-4. The free space technique is being used in lieu of the shorted waveguide method. The shorted waveguide method requires dielectric samples to have close tolerances in order to accurately fit into the 0.28- by 0.14-inch Ka-band waveguide. Loss tangent characteristics are not being determined. Several one-foot-square fiberglass panels, manufactured by Republic Aviation, are being evaluated. These panels have been fabricated with various cloth types (164 and 181) and resin contents (42 to 47%). Material thickness has also been varied from two layers of cloth (.022 inch) to six layers of cloth (.072 inch). A teflon sample is being utilized as a standard because of its small variation in dielectric constant at room temperature, i.e., 2.10 at 100 cycles to 2.08 at 25 gigacycles as reported by A. R. Von Hippel in a 1954 M.I.T. publication "Dielectric Materials and Applications".

Dielectric constants are being obtained with the insertion phase difference (IPD) method through air with and without a sample. Typical dielectric constants at 38 gigacycles range from 2.068 to 2.087 for teflon, 3.527 to 3.581 for 181 cloth and 4.620 to 4.675 for 164 cloth. The entire Ka-band, from 26 to 40 gigacycles, is being surveyed.

Preliminary observations to date have pointed up the requirements for:

1). Close tolerances and critical adjustments at Ka-band frequencies due to the small wavelengths (7.5 to 11.3 millimeters).

2). Close control of frequency measurement due to klystron signal source frequency drift.

Type of Program: Engineering Evaluation

Material Classification: Plastics

Descriptive Title: Epon VIII, Crazing of Acrylics

Objective: Determine the effect of Epon VIII on acrylic materials.

Abstract of Results and Conclusions: Two acrylic materials, Plexiglas 1 and Plexiglas 55, were tested for compatibility with Shell adhesive Epon VIII. Compatibility was determined with an accelerated crazing test performed in accordance with paragraph 4.5.9 of MIL-S-7126d. The test procedure entailed loading a 1 x 7 x .025 adhesive coated specimen in flexure for 24 hours, maintaining a maximum fibre stress of 2000 psi. Both Plexiglas 1 and Plexiglas 55 showed no crazing effect upon completion of testing.

Type of Program: Engineering Evaluation

Material Classification: Sealants

Descriptive Title: Integral Fuel Tank Sealants

Objective: This study was initiated to evaluate sealants for integral fuel tanks for operating temperatures ranging from -67° to 400°F.

Abstract of Results and Conclusions: A screening test of several basic sealants such as silicones, vitons, and polysulfides was conducted to determine the suitability of various sealants for application to integral fuel tanks operating at temperatures ranging from -67° to 400°F. Results of the screening program showed that Products Research Corporation's sealant PR1730 (a Viton A base compound) was the only sealant capable of satisfying the temperature requirements. Additional evaluation of PR1730 sealant was conducted in accordance with Specification MIL-S-8802B with modifications as suggested by AIA Specification ARTC-13. Results of these tests showed that PR1730 sealant with PR1734 primer was unsatisfactory for integral fuel tanks in view of the poor adhesion characteristics and mode of failure during peel tests. For the above sealant system, peel load required to initiate an adhesive failure was 10 to 20 pounds per inch. However, the peel load required to propagate the failure was 3 to 5 pounds per inch.

Additional tests were conducted employing a two-part primer system, PR1732 and PR1733. The mode of failure was similar to the previous systems tested but the initial adhesive failure load was 30 to 45 pounds per inch. Load required to propagate the failure was the same as in previous tests. Additional investigations are being conducted to improve the adhesion characteristics of this sealant system.

Type of Program: Engineering Evaluation

Material Classification: Miscellaneous Special Purpose Materials

Descriptive Title: Power Generation Characteristics of Silicon Solar Cells

Objective: This program was initiated to investigate the application of illumination intensity concentrator techniques to increase the power output of silicon solar cells. The program was expanded to include the evaluation of two new types of solar cells: gridded and blue gridded silicon solar cells.

Abstract of Results and Conclusions: The measurements of the power output and conversion efficiency of the solar cells were performed under natural sunlight, tungsten and mercury-xenon arc illumination. The level of illumination and temperature of each test sample cell was monitored on a water-cooled test stand, and the variation of maximum power was recorded as these parameters were varied. The application of a reflection-type concentrator will produce a power gain in the 3 to 1 range. The internal impedance of each cell is lower with the concentrator, but the cell temperature increases. Maximum power with concentrators can be achieved if the cell temperature is maintained at a low fixed value. This condition is an important design consideration since the conversion efficiency of a cell increases with decreasing temperature.

The two new types of silicon solar cells, gridded and blue gridded, were tested to determine the improvement over the standard type silicon cell. The method of gridding the front surface of the cell improved the collection efficiency of the P junction and would yield a higher efficiency over the standard cells. The improved ultraviolet response of the blue cell increased the power output by more accurately matching the spectral distribution of sunlight with solar cell response. Application of these new type cells would increase the total conversion efficiency and power output of a solar power supply.

Type of Program: Engineering Evaluation

Material Classification: Miscellaneous Special Purpose Materials

Descriptive Title: Chemical Descaling of Rene' 41 Sheet Material

Objective: To determine whether a chemical descaling method can be substituted for costly vapor blast operation without a resulting degradation in mechanical properties.

Abstract of Results and Conclusions: Four chemical descaling methods were compared with the vapor blast descaling method. These descaling methods were evaluated with room temperature and 1400°F tensile tests and room temperature flexure fatigue tests. Subsequent evaluation of test data revealed that the test material (.025 sheet) was below specification. These tests are presently being rerun with specification material. Hydrogen pick up of the base material, after chemical cleaning, is also being evaluated. The most effective chemical cleaning process found to date is a 10-minute immersion in HNO_3/HF (20/4 percent by weight) maintained at 120-140°F.

Type of Program: Engineering Evaluation

Material Classification: Miscellaneous Special Purpose Materials

Descriptive Title: Chemical Cleaning of B120 VCA Titanium

Objective: To determine the effects of chemical cleaning (descaling) on the mechanical properties of B120 VCA Titanium.

Abstract of Results and Conclusions: Chemical cleaning techniques were evaluated for ease of scale removal after thermal processing of B120 VCA sheet material (0.018 inch gage). Chemical descaling is generally the most economical and efficient process for scale removal, compared with mechanical cleaning techniques. To date, the most effective method was a 3-minute immersion in HNO_3/HF (30/3 percent by weight) solution maintained at room temperature.

The effects of this acid treatment on the tensile strength and modulus (at both room temperature and 600°F), flexural fatigue, hydrogen pick-up, and surface smoothness of the metal are being determined.

Type of Program: Engineering Evaluation

Material Classification: Miscellaneous Special Purpose Materials

Descriptive Title: Drive-Matic Riveting without the use of a Wet Primer

Objective: To evaluate the effect of eliminating wet zinc chromate primer for riveting applications when using the Drive-Matic Riveting machine.

Abstract of Results and Conclusions: A series of riveted 7075 alclad test panels, employing flush head aluminum rivets, was assembled with a Drive-Matic Riveting machine. The panels were assembled both with and without the use of the wet zinc chromate primer. The panels were subjected to acetic acid salt spray tests in conformance with ASTM B-287-57T for 248 hours. The tests indicated no evidence of corrosion when the wet primer was eliminated.

Type of Program: Processing Development

Material Classification: Metallics - General

Descriptive Title: Hot Forming Titanium and Nickel Base Alloys in Inert Atmospheres

Objective: Develop practical techniques for the atmospheric protection of titanium and nickel base alloys during hot forming operations.

Abstract of Results and Conclusions: Two techniques for shielding hot forming operations are being investigated:

1) the use of a rigid enclosure which opens to permit access to the tools,

2) the use of a flexible enclosure employing hand holes or other means to manipulate work. Equipment is being designed to operate at 1500 - 2000°F using Argon or possibly less expensive gas such as nitrogen for shielding. Tests will be conducted to establish economical operation suitable for production applications.

Manufacture of shielding equipment has been initiated. A matched male and female forming die has been cast to finished size in Inconel 713C. A universal die heating unit is also in the process of being manufactured.

Upon completion of the initial set of equipment, tests will be initiated to determine effect of various atmospheres and forming temperatures on material properties. Limited testing will be conducted with molybdenum, tungsten, and beryllium as well as with titanium and nickel base alloys for which the process is primarily being developed.

Type of Program: Processing Development

Material Classification: Metallics - General

Descriptive Title: Capacitor Discharge Metal Forming

Objective: To determine the formability of various yield strength metals in underwater capacitor discharge forming, and to develop a process for forming rocket cases and missile domes. (AF33(600)-42920)

Abstract of Results and Conclusions: A state of the art survey conducted in Phase I indicated that several organizations have satisfactorily formed small tubular parts and dished sheet parts by capacitor discharge forming. Very little work has been done in the area of developing the process by investigation of process parameters.

Phase II work has been conducted to determine effectiveness of process parameters such as energy level, discharge power, initiation wire material, wire diameter and length, and liquid transfer medium. The efficiency achieved in the conversion of stored energy into deformation (strain) work ranges from 10% for stainless steel to 25% for aluminum alloys.

Work on Phase III has just been initiated. This phase of the program is concerned with the influence of process parameters upon the efficiency of forming 24" diameter dome specimens in 2024-T Aluminum, 4130 Steel, 6AL-4V Titanium alloy, Rene' 41, and Columbium. In addition, the feasibility of expanding heavy wall 10" diameter steel cylinders will be investigated.

In Phase IV, configurations of current aerospace vehicle interest will be selected to determine the capability or limitations of the capacitor discharge forming equipment. Several parts in two selected configurations will be formed to establish reproducibility, tolerance, and cost.

Type of Program: Processing Development

Material Classification: Metallics - General

Descriptive Title: Investigation of Ultrasonic Welding of Thin Material

Objective: To develop weld parameters and mechanical property data for ultrasonic welded thin gage materials.

Abstract of Results and Conclusions: This investigation is presently being conducted to determine welding parameters and mechanical data for thin gage joints of similar and dissimilar material combinations. The materials under investigation have been limited to stainless steel and aluminum alloys in foil gages of approximately .002 to .004. The present study involves determination of attainable strength levels and consistency of quality welds. Improved welding tip configurations are also under evaluation.

Type of Program: Processing Development

Material Classification: Titanium

Descriptive Title: Fusion Welding of B120VCA Titanium and Response of Weldments to Heat Treatment

Objective: To investigate the response of weldments to various heat treat cycles and develop a heat treatment which will produce compatible optimum properties in both weldment and base metal.

Abstract of Results and Conclusions: A limited test program has been conducted on post weld heat treatment of fusion welded material. Two gages of material, .015 and .040, were evaluated. Several simple and multi-stage aging cycles were evaluated with .040 material. The most satisfactory aging cycle was achieved with a double aging cycle, i.e., 900°F for 50 hours plus 1050°F for 5 minutes. An ultimate strength level of 190 KSI, a yield strength of 170 KSI, and an elongation of 4.5% in 2 inches was achieved. Subsequent evaluation of this aging cycle with .015 material was not satisfactory. Strength levels were generally lower and elongation was extremely low (ultimate strengths ranged from 170 to 180 KSI, yield strengths ranged from 160 to 168 KSI, and elongations ranged from 0 to 1.5%).

Type of Program: Processing Development

Material Classification: Titanium

Descriptive Title: Tungsten Inert Gas Spot Welding Investigation of B120VCA Titanium

Objective: To establish weld parameters for tungsten inert gas spot welding of B120VCA Titanium, develop process techniques and generate design data for welding in the annealed and heat treated conditions.

Abstract of Results and Conclusions: B120VCA Titanium has been successfully tungsten inert gas spot welded in the annealed and heat treated conditions. The mechanical property results (lap shear and cross tension values) met the requirements of MIL-W-6858B. Unequal gage combinations may be welded (thick to thin) in a ratio larger than three to one provided the bottom sheet is supported. It was also concluded that the fit-up is very critical and sheets to be welded must have intimate contact. Cleaning of the material prior to welding is also critical in order to insure uniform welds of high quality.

Type of Program: Processing Development

Material Classification: Nickel

Descriptive Title: Welding Investigation of Astroloy

Objective: To determine the weldability of Astroloy and the optimum welding-heat treatment sequence.

Abstract of Results and Conclusions: An investigation is being conducted to determine weld parameters and optimum sequence of welding and heat treating. After weld parameters have been established, further studies will be made to test the welds for consistency and strength levels in the following conditions:

1. Spot and fusion weld in the solution treated condition (as received) then tested.
2. Spot weld in the aged condition and tested.
3. Spot and fusion weld in the solution treated condition then aged after welding, and tested.
4. Spot and fusion weld in the solution treated condition, re-solution heat treated, aged and tested.

In conjunction with the above conditions, lap shear, tensile, cross tension and fatigue test will be conducted at room and elevated temperatures where applicable.

Type of Program: Processing Development

Material Classification: Refractory Alloys

Descriptive Title: Preliminary Refractory Metal Welding Investigation

Objective: To determine the weldability of three refractory metals, FS-82 Columbium, TZM Molybdenum, and Tantalum-10% Tungsten.

Abstract of Results and Conclusions: Very basic butt and spot welding studies are being conducted for three refractory alloys. These alloys include FS-82 Columbium, TZM Molybdenum and Tantalum-10% Tungsten. These studies include the development of weld parameters in both processes. Following the refinement of welding techniques, tensile, lap shear, cross tension, radiographic and metallographic tests will be made where applicable.

Type of Program: Processing Development

Material Classification: Refractory Alloys

Descriptive Title: Preliminary Fabrication Characteristics of Refractory Alloys

Objective: To determine preliminary fabrication characteristics of three refractory alloys, FS-82 Columbium, TZM Molybdenum, and Tantalum-10% Tungsten.

Abstract of Results and Conclusions: Preliminary fabrication studies have been initiated on three refractory alloys (TZM, FS-82, and Ta-10W). Methods of shearing, forming, machining and cleaning will be evaluated. Preliminary forming with FS-82 has verified the ductile quality of the material. Minimum bend radii of 1T and stiffener beads with a 4:1 width to depth ratio can be obtained at room temperature with conventional forming equipment.

Metallurgical studies are being conducted concurrently to determine the influence of structure on fabrication and machinability. The materials are examined during the various stages of fabrication to evaluate effects of processing. Parameters under investigation are size, direction, and uniformity of grain, presence of defects and impurities, and level and depth of contamination. Recrystallization and stress relief studies will be conducted, and mechanical property tests will be performed at room and elevated temperature.

Type of Program: Processing Development

Material Classification: Refractory Alloys

Descriptive Title: Welding Investigation of Cb-74 Columbium

Objective: To determine the weldability of Cb-74 Columbium and to obtain mechanical property data of the welds at room and elevated temperatures.

Abstract of Results and Conclusions: One spot weld and one continuous butt weld technique will be developed for the Cb-74 Columbium alloy. Preliminary studies are under way that will lead to the development of weld parameters. After welding techniques for the Cb-74 have been developed and refined, specimens will be fabricated to test the butt welding process in tensile strength and fatigue at room and elevated temperatures, and the spot welding process in shear, fatigue and cross tension at room and elevated temperatures. On completion of these tests, small structural corrugated panels will be spot welded and bend tested at room and elevated temperatures. All elevated temperature specimens will be coated with a suitable oxidation protective coating prior to testing.

Type of Program: Processing Development

Material Classification: Plastics

Descriptive Title: Development of Plastic Mold Dies

Objective: To develop a casting resin formulation to enable the manufacture of self-heating mated dies for fabrication of reinforced plastic aircraft parts.

Abstract of Results and Conclusions: A number of commercially available casting resins, as well as newly formulated proprietary thermosetting resins, are being evaluated for use as self heated mated die materials. Commercial resins have included those available from Furane Resins & Coatings Company, Marbellette Corporation, Smooth-On Corporation, Ren Corporation, etc. The study of selected resins includes measuring thermal conductivity, heat distortion temperature, compression strength, and impact resistance.

To date, the most successful casting material was an aluminum filled anhydride cure epoxy-novalac resin. Investigation of effects of inert fillers, filler size and shape, curing agents, suspension agents, and casting techniques will continue until small scale tools appear feasible. At that point, an actual production die will be fabricated, and die life and cost data will be obtained.

Initial studies have shown that this technique of die manufacture is both feasible and economical.

Type of Program: Processing Development

Material Classification: Plastics

Descriptive Title: Splining Plastic Resins for Mockups

Objective: To determine the suitability of thermosetting plastics for splined aircraft mockup.

Abstract of Results and Conclusions: Specially formulated epoxy resins are being evaluated for use as splining material. The physical parameters and characteristics such as viscosity, thixotropy, density and ease of handling are being determined.

The most efficient formulation obtained will be used to build a full scale F-105D winglet mockup. This mockup will be compared to a conventional plastic mockup manufactured at the same time. The evaluation will consist of cost data, thermal stability, storageability, and surface accuracy.

It is anticipated that splining of plastic resins will be successful and will be superior to the plaster mockup from the viewpoints of dimensional stability, storageability, and useability.

Type of Program: Processing Development

Material Classification: Coatings

Descriptive Title: Heat treat protective coatings for Nickel base alloys

Objective: To develop a coating material and process to protect Nickel base alloys from scaling when heat treated in an oxidizing atmosphere.

Abstract of Results and Conclusions: A number of commercial heat treat protective coatings, such as Turco Pre-treat, Tempil-Pyromark 70829 and 70933, Pemco RA225 and 227, Ace Laboratory C-2943, etc., have been evaluated for use at 2000°F on Nickel base alloys. A satisfactory coating must be capable of protecting the base material during thermal processing such as 16 hours at 1400°F and 45 minutes at 1900°F. The coatings are being evaluated for:

1. Minimum requirements for pre-cleaning.
2. Cleaning action provided by the coating itself, without actual attack of the base material.
3. Simple method of application.
4. Good coverage and protection during thermal processing.
5. Simple method of removal.

To date none of the coatings tested have been completely satisfactory. Several proprietary coatings are also being evaluated.

Type of Program: Processing Development

Material Classification: Miscellaneous Special Purpose Materials

Descriptive Title: Chemical Milling of Refractory Materials

Objective: To develop chemical etchants and related process variables for chemical milling of refractory metals and refractory oxides.

Abstract of Results and Conclusions: Development of the chemical milling process has just been initiated for refractory materials. This program will include study of power chem milling (AC or DC power), fused salt techniques, and acid/alkali methods. In addition, any currently available etchants will be evaluated. The process variables to be studied will be etch rate, etch factor, surface smoothness, and masking techniques. If successful, the program will be expanded to include taper chem mill and chemical milling of ceramics in general.

Type of Program: Testing Technique

Material Classification: Emittance

Descriptive Title: Emittance Program

Objective: To develop instrumentation for performing and automatically recording angular emittance measurements.

Abstract of Results and Conclusions: Equipment is being assimilated for measuring spectral and total angular emittance. Test materials, applied to conducting substrates, will be resistance heated. The sample holder is designed for goniometric viewing and operation in controlled environments. Power input to the sample and temperature control is derived from a 7.5 KVA (maximum) saturable core type power supply. The power output is slaved to a reference blackbody temperature via a differential thermocouple.

The present optical system permits the measurement of spectral radiation in the wavelength interval from 0.3 to 15 microns while simultaneously viewing total (i.e. undispersed) inputs from the same source.

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